

This **Microfocus-Source/Polycapillary-Collimator X-Ray System** generates an x-ray flux greater than that of a larger and more power-hungry rotating-anode x-ray system.

mize the collimated x-ray flux. The spectrum from the source contains a significant component of Cu K $\alpha$  (photon energy is 8.08 keV) radiation. The beam is monochromatized (for Cu K $\alpha$ ) by a nickel filter 10  $\mu$ m thick.

In a test, this system was operated at a power of 40 W (current of 897  $\mu$ A at an accelerating potential of 45 kV), with an anode x-ray spot size of  $41 \pm 2$   $\mu$ m. Also tested, in order to provide a standard for comparison, was a commercial rotating-

anode x-ray crystallographic system with a pyrolytic graphite monochromator and a 250- $\mu$ m pinhole collimator, operating at a power of 3.15 kW (current of 70 mA at an accelerating potential of 45 kV). The flux of collimated Cu K $\alpha$  radiation in this system was found to be approximately 16 times that in the rotating-anode system. Data on x-ray diffraction from crystals of tetragonal form of lysozyme (protein) in this system were found to be of high quality and to be re-

ducible by use of standard crystallographic software.

*This work was done by Marshall Joy of **Marshall Space Flight Center**, Mikhail Gubarev of the National Research Council, and Ewa Ciszak of Universities Space Research Association.*

*This invention is owned by NASA, and a patent application has been filed. For further information, contact Jim Dowdy, MSFC Commercialization Assistance Lead, at [jim.dowdy@nasa.gov](mailto:jim.dowdy@nasa.gov). Refer to MFS-31499.*

## **Depth-Penetrating Luminescence Thermography of Thermal-Barrier Coatings**

**Temperatures at depths can be measured by luminescence decay of suitable thermographic phosphors.**

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A thermographic method has been developed for measuring temperatures at predetermined depths within dielectric material layers — especially thermal-barrier coatings. This method will help satisfy a need for noncontact measurement of through-the-thickness temperature gradients for evaluating the effectiveness of thermal-barrier coatings designed to prevent overheating of turbine blades, combustor liners, and other engine parts.

Heretofore, thermography has been limited to measurement of surface and near-surface temperatures. In the thermographic method that is the immediate

predecessor of the present method, a thermographic phosphor is applied to the outer surface of a thermal barrier coating. Luminescence in the phosphor is excited by illuminating the phosphor at a suitable wavelength, and either the time dependence of the intensity of luminescence or the intensities of luminescence spectral lines is measured. Then an emissivity-independent surface-temperature value is computed by use of either the known temperature dependence of the luminescence decay time or the known temperature dependence of ratios between intensities of selected luminescence spectral lines. Until

now, depth-penetrating measurements have not been possible because light of the wavelengths needed to excite phosphors could not penetrate thermal-barrier coating materials to useful depths.

In the present method as in the method described above, one exploits the temperature dependence of luminescence decay time. In this case, the phosphor is incorporated into the thermal-barrier coat at the depth at which temperature is to be measured. To be suitable for use in this method, a phosphor must (1) exhibit a temperature dependence of luminescence decay time in the desired range, (2) be thermochemi-

cally compatible with the thermal-barrier coating, and (3) exhibit at least a minor excitation spectral peak and an emission spectral peak, both peaks being at wavelengths at which the thermal-barrier coating is transparent or at least translucent.

Conventional thermographic phosphors are not suitable because they are most efficiently excited by ultraviolet light, which does not penetrate thermal-barrier coating materials. (Typical thermal-barrier coating materials include or consist of various formulations of yttria-stabilized zirconia.) Only a

small fraction of phosphor candidates have significant excitation at wavelengths long enough ( $>500$  nm) for sufficient penetration of thermal-barrier coatings. One suitable phosphor material — yttria doped with europium ( $\text{Y}_2\text{O}_3\text{:Eu}$ ) — has a minor excitation peak at 532 nm and an emission peak at 611 nm. In experiments, this material was incorporated beneath a 100- $\mu\text{m}$ -thick thermal-barrier coating and subjected to excitation and measurement by the luminescence-decay-time technique. These experiments were found

to yield reliable temperature values up to 1,100 °C. At the time of reporting the information for this article, a search for suitable phosphors other than ( $\text{Y}_2\text{O}_3\text{:Eu}$ ) was continuing.

*This work was done by Jeffrey Eldridge of Glenn Research Center. Further information is contained in a TSP (see page 1).*

*Inquiries concerning rights for the commercial use of this invention should be addressed to NASA Glenn Research Center, Commercial Technology Office, Attn: Steve Fedor, Mail Stop 4-8, 21000 Brookpark Road, Cleveland Ohio 44135. Refer to LEW-17617-1.*

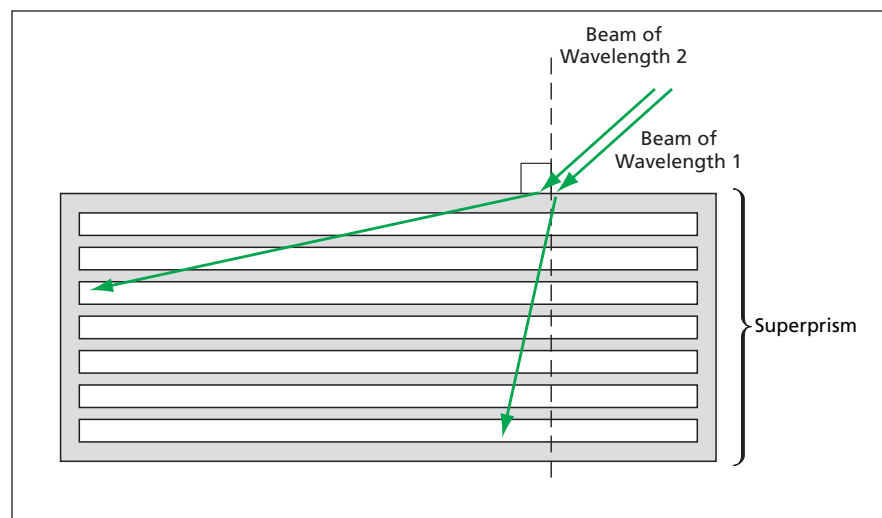
## One-Dimensional Photonic Crystal Superprisms

**In comparison with three-dimensional superprisms, these could be fabricated more easily.**

*NASA's Jet Propulsion Laboratory, Pasadena, California*

Theoretical calculations indicate that it should be possible for one-dimensional (1D) photonic crystals (see figure) to exhibit giant dispersions known as the superprism effect. Previously, three-dimensional (3D) photonic crystal superprisms have demonstrated strong wavelength dispersion — about 500 times that of conventional prisms and diffraction gratings. Unlike diffraction gratings, superprisms do not exhibit zero-order transmission or higher-order diffraction, thereby eliminating cross-talk problems. However, the fabrication of these 3D photonic crystals requires complex electron-beam substrate patterning and multilayer thin-film sputtering processes.

The proposed 1D superprism is much simpler in structural complexity and, therefore, easier to design and fabricate. Like their 3D counterparts, the 1D superprisms can exhibit giant dispersions over small spectral bands that can be tailored by judicious structure design and tuned by varying incident beam direction. Potential applications include miniature gas-sensing devices.



**A One-Dimensional Superprism** could be fabricated more easily than a three-dimensional superprism. Like a three-dimensional prism, it would exhibit strong wavelength dispersion: two beams of light incident at the same angle and having slightly different wavelengths would be refracted at two widely different angles.

*This work was done by David Ting of Caltech for NASA's Jet Propulsion Laboratory. Further information is contained in a TSP (see page 1).*

*This invention is owned by NASA, and a patent application has been filed. Inquiries*

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